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ALBA BOREAS Beamline 29 MARES End Station detectors design, ALBA-CELLS Synchrotron light source

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Abstract **-**BOREAS beamline at ALBA synchrotron facility is soft X-ray beamline dedicated to polarization-dependent spectroscopic investigations of advanced materials. The second End Station, MARES (magnetic resonance scattering) is a reflectometer for a scattering in a UHV environment. For this purpose, the system has a ϴ, 2ϴ rotary feedthrough that allows the positioning of detectors and samples in the appropriate configuration to perform the experiment. ALBA engineering division has developed two mechanical arms to place different detectors, one in-vacuum CCD camera and one channeltron device (with additional diodes). The main goals of designs were to achieve high resolution, accuracy and stability. The concept of the two detectors is a classic mechanical system that moves the detector inside vacuum chamber in Z direction. The whole mechanism is separated in two assemblies; the external one mounted at air side, basically the mechanics, and the internal one, the detectors with an in-vacuum arm support. With this solution, main design goals have been achieved, these are the some important results: first resonance modes of systems are being moved over 35Hz to avoid floor resonance amplifications. Regarding positioning performances, CCD camera system has a 155mm range inside vacuum with 1µm resolution. Channeltron system has a 100mm range inside vacuum with 1µm resolution too. All material used are UHV compatible, bakeable and especially non-magnetic in order to not disturb the magnetic field of station cryomagnet. In addition, some in-vacuum piezoelectric precision movement systems have been introduced to move detectors shutters or slits. These components simplify the design, keeping the capabilities of detectors. Finally, to reach a proper design several solutions have been analyzed, with FEA tools, to validate a compromise solution which has been produced and tested.

1. Introduction

MARES is the second End Station of BL29, BOREAS, at ALBA Synchrotron. It is a complex instrument with a huge number of subsystems that interact to perform the different experiments. The mechanical systems of the end station are being developed by engineering division.

Two of the most important subsystems are the detector arms designed to hold different type of sensors. The first one is an in-vacuum CCD camera holder and the second, is a Channeltron, MCP and diodes holder. Both systems have to accomplish with the scientist demands, which are exposed on the following chapter.

2. Technical specifications

The main specifications for both systems are listed below:

- No magnetic materials due to the high magnetic fields that are involved during experiments.
- A Z movement is needed to position the detectors during experiments.
- Regarding mechanical stability, minimum deformation of the system is needed and the system must be as rigid as possible. Taking into account the floor excitations, resonance modes of the system have to be more that 35-40Hz.
- The mounting interphase of the whole system with the End Station is a DN100CF flange.
- The travel of the z-motion must be as long as possible. A high movement resolution is needed (between 1-5µm).
- Finally, every system has a specific environment on the detector. The CCD arm has to include a shutter (and screen) in front of the sensor. And, the Channeltron arm has to include a slits setup to collimate the incident beam.

3. Conceptual design

Taking into account the previous specifications and the characteristics of the system where the detectors arms will be mounted, it had decided to separate the system into two different parts. The first one is the motion part at air, where all the movement components are placed, like motor, spindle and guides. The second part is totally in-vacuum and supports the different sensor at every case.

Regarding the mechanics, that are the same in both cases, the following devices have been considered: Stepper motor with a low backlash reduction of 1:100 (Web-4). Linear precision guides with preloaded carriages (Web-2). Ball spindle preloaded of 20mm diameter with 5mm advance (Web-1). According all of these elements, the expected resolution is less than 0,5µm (1).

$$r = \frac{5\,mm}{1\,rev} \cdot \frac{1}{100} \cdot \frac{1\ rev}{200\,steps} \cdot \frac{1000\ \mu m}{1\,mm} = 0{,}25\mu m < 0{,}5\mu m \qquad (1)$$

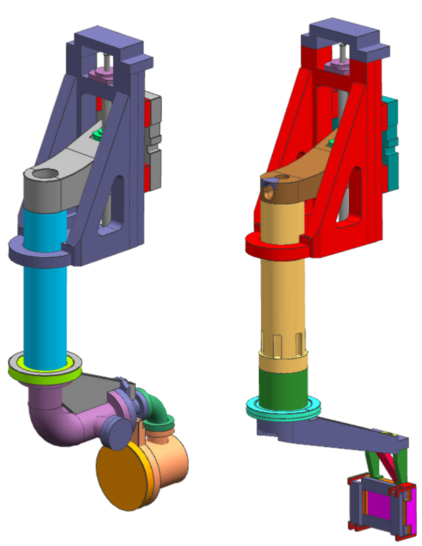

Fig. 1. Conceptual design of two detector arms

In addition, every detector has a suitable holder or accommodation to place the different sensors that are involved. All materials are no magnetic and bakeable up to 120ºC.

3. 1. CCD detector shutter

The CCD camera during no operation must be shuttered. For this reason, is introduced a standard component of Smaract® (Web – 3). This is an in-vacuum piezo-actuator with a very precise and compact linear movement. Using this device, there are three available work positions: fully shuttered, fully opened with a screen and fully opened (with a beam stopper option). The solution is shown on the following figure:

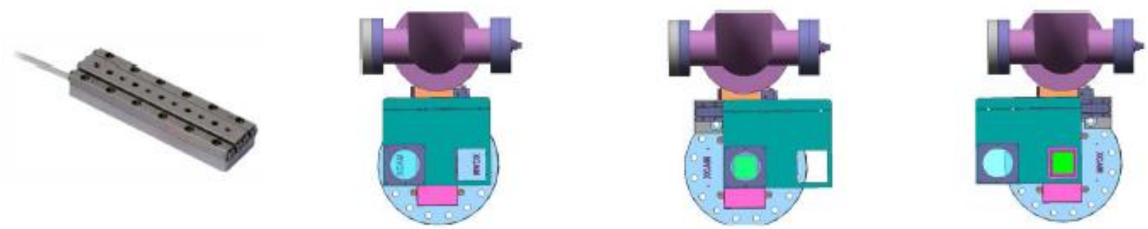

Fig. 2. Smaract system used with the three work positions

3. 2. Channeltron detector slits

In this case, there are a big number of sensors (Channeltron, MCD and diodes). During the experiments, only one of them must be working. In addition, the possibility of collimate the light entrance to the sensor must be consider. Taking into account these considerations, a slits solution is implemented. Using four Smaract®, one for every blade, a slits system can be produced in front of the sensors. Any footprint can be achieved on the sensors, from 0 to 45x45mm with 1nm resolution and repeatability of 50nm.

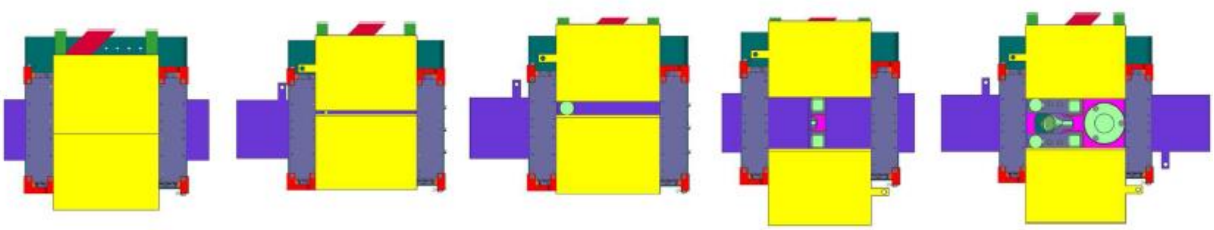

Fig. 3. Slits systems with four Smaract. Footprint available from 0 to 100% at every sensor

4. Simulations

To validate the conceptual design of detector arm, some FEA calculations have been done. The modeling of the system has been done taking into account the properties of every involved material. Regarding the movable elements, the total stiffness of the spindles and support has been calculated and a soft material has been introduced to simulate the stiffness of the linear guides, applying the values according the datasheets.

Once the models are fulfilled, two different simulations are done. First static behavior analysis is done to quantify maximum stresses (Von Misses stress) and displacements. The second free vibration analysis is done to kwon the system resonance modes. The results are shown on the following chapters.

4. 1. CCD arm detector

On CCD arm detector, the different loads have been applied. In addition, there is an estimation of the impact of ±5% deviation on the atmospheric pressure. The results are the following:

Table. 1. CCD arm FEA results

Characteristic	***Value***
Maximum stress	26,5 MPa
Maximum deformation (adjustable)	0,087 mm
Maximum deviation (adjustable)	69,9 μrad
Maximum deviation variation ±5% (uncertainty)	±3,5 μrad

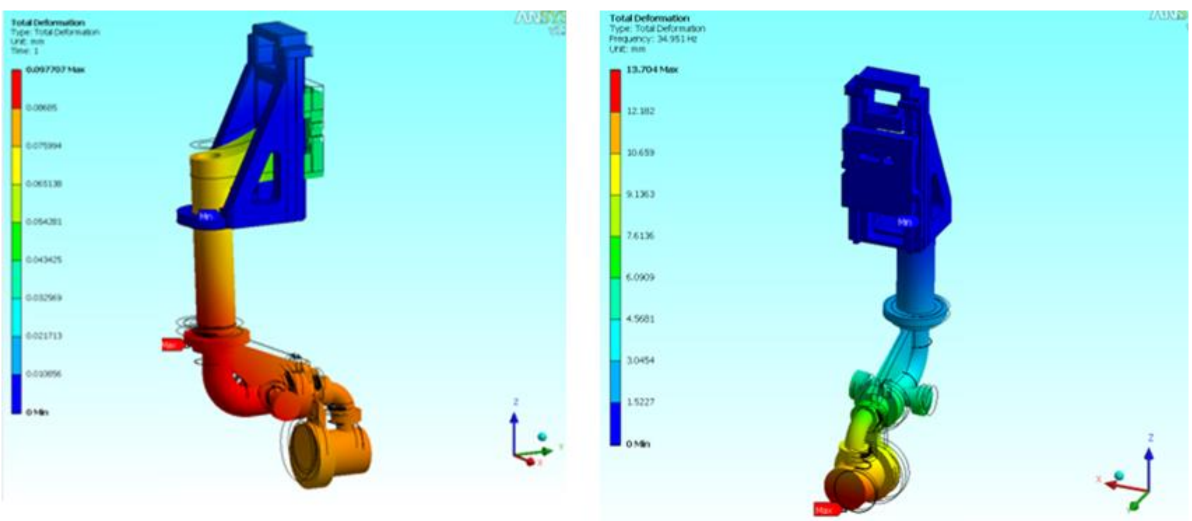

Fig. 4. Left, maximum deformation results; right, first resonance mode

The first resonance mode of the system that appears is at 35Hz that can be considered acceptable.

4. 2. Channeltron arm detector

Following the same procedure, on Channeltron arm detector, the different loads have been applied and the results are the following:

Table. 2. Channeltron arm FEA results

Characteristic	*Value*
Maximum stress	34 MPa
Maximum deformation (adjustable)	0,21 mm
Maximum deviation (adjustable)	297 µrad
Maximum deviation variation ±5% (uncertainty)	±13,1 µrad

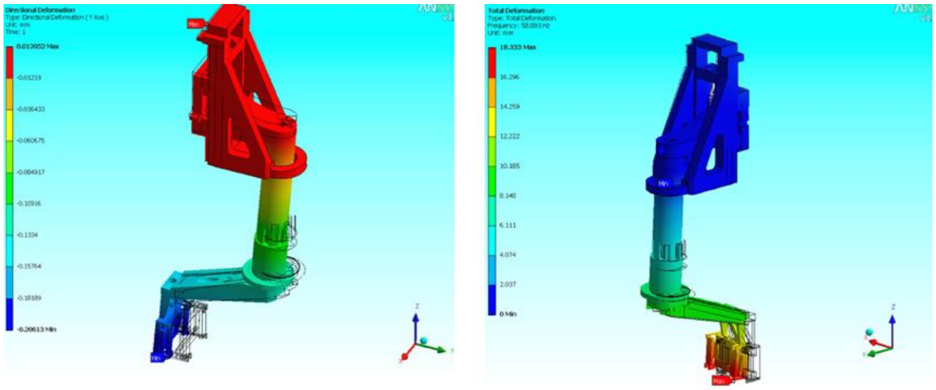

Fig. 5. Left, maximum deformation results; right, first resonance mode

The first resonance mode of the system that appears is at 59Hz that can be considered acceptable.

5. Detailed design. Manufacturing and assembly

After the approval of the two systems, the designs have been detailed. Standard mechanical connections, cable chain, final integration have been introduced on the detailed design. These designs are shown on the following figure:

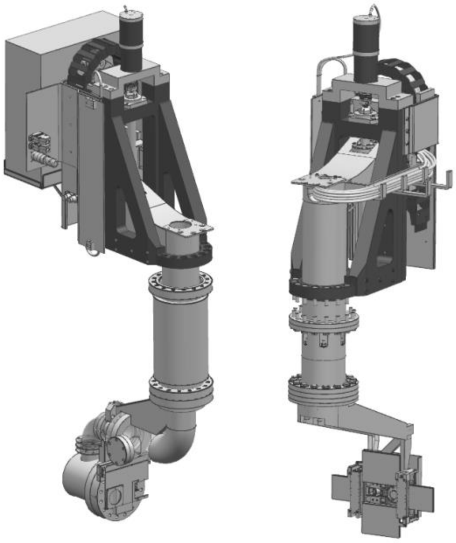

Fig. 6. Left, CCD detector arm; right, Channeltron detector arm

The manufacture of the different parts that compound the two arms have separated between conventional mechanical workshops to produce the air precision parts and vacuum companies to produce the internal features.

Regarding assembly, it has been done at CELLS mechanical workshop with the suitable adjustments. Some details of the final assembly are shown on the following figure:

Fig. 7. Details of final CCD and Channeltron detector arms assembly

6. Testing

To verify the different calculations of the conceptual designs, some tests have been performed. One test of mechanics movement to obtain the resolution and repeatability, and other test to kwon the free vibration of every detector arm. These are the results of the detectors mechanics:

Table. 3. Repeatability tests, done by interferometer

Characteristic	***Value***
Resolution	0,125 µm
Repeatability	3,6 µm
Linearity	15 µm

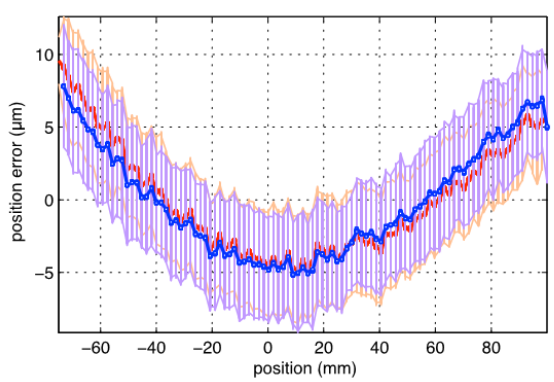

Fig. 8. Mechanics repeatability test results

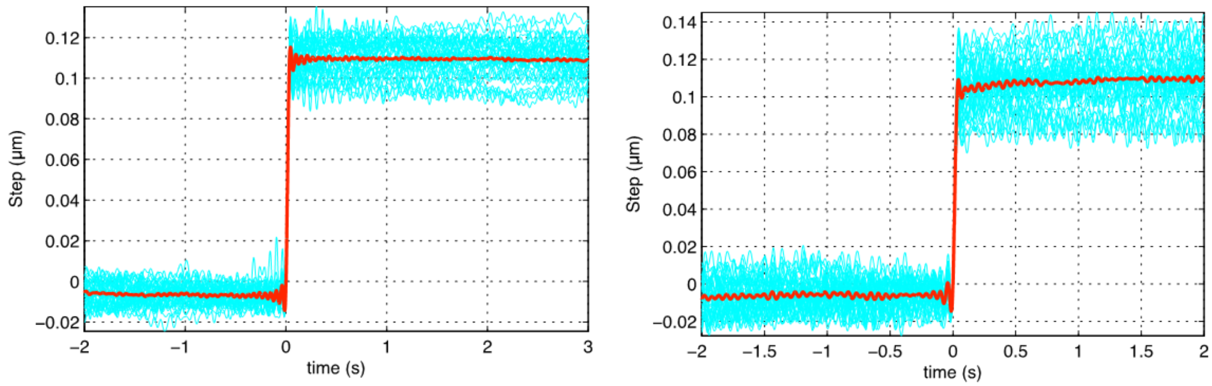

Fig. 9. System step response. CCD arm left, Channeltron arm right

Regarding the resonance modes, first the background has been measured. After the results are:

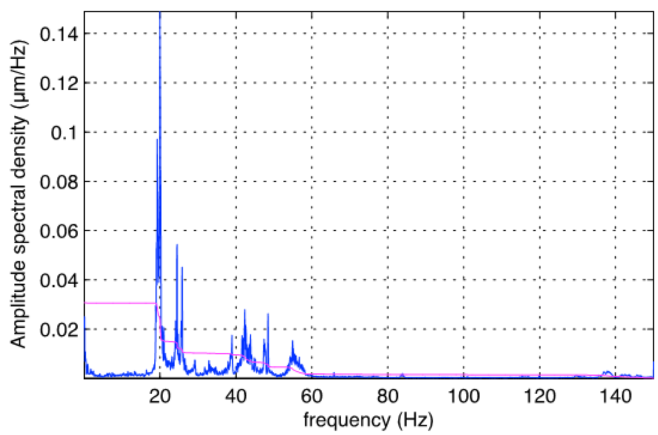

Fig. 10. Background measurement, some peaks introduced by the test bench

Table. 4. Stability tests results taking into account the bench perturbations

Characteristic	***Value***
CCD arm	39Hz
Channeltron arm	42Hz

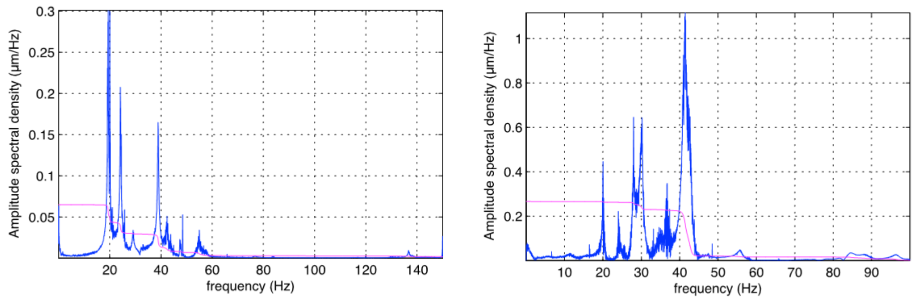

Fig. 11. Left, CCD test results; right Channeltron test results.

7. Conclusions

BOREAS beamline at ALBA Synchrotron needed two arm detectors to continue with the commissioning and operation of the second End Station, MARES.

Two precise z-motions have been developed to move inside the vacuum chamber different sensors or cameras. The systems are able to work at different positions and with different capabilities during the experiments, for example the slits system on Channeltron detector arm. In addition, the systems have a high stability to ensure good measurements during the experiments. The detectors arms are prepared to be installed into the End Station and start de commissioning.

It is very important to comment that, in spite of space, the design of two rigid and robust mechanics has been possible. Good capabilities of the systems are achieved, for instance, the final resolution is better than the value asked on the start technical specifications. To finish, the resonance modes of the systems have been predicted with a small error as it has been shown.

Acknowledgements

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Web sites:

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Web-2: http://www.schneerberger.com/

Web-3: https://www.smaract.de/

Web-4: http://www.skf.com/

Web-5: http://www.phytron.com/